MODIS Science Team Member
Semi-Annual Report *
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a) Task Objectives

During this phase of the project, we continued research on the 'at-launch' MODIS atmospheric correction suite of algorithms, which include surface reflectance, vegetation index, fire detection processing. This work culminated in our Version 1 code, delivered to the Science Data Support Team (SDST) in June 1996, meeting the target date. This group took responsibility for merging the various team member contributions into the Modland Validation Document and Overheads. The group also worked closely with SDST (David Roy) to develop the first draft of the Modland Quality Assurance (QA) plan. During this reporting period Justice endeavored to increase attention being given to Instrument Testing by requesting that a schedule be developed for delivery of testing results. Thanks to the timely involvement of the MODIS Project Scientist, this request provided the impetus for the current critical focus on instrument performance.

We continued to build the infrastructure and collaboration required to conduct the work of developing community consensus algorithms. Materials on each of the products were presented at the SWAMP Land Review. The project has developed a number of collaborative projects that are intended to expand the scope of the team membersÕ activities and involve a larger community in MODIS research. Due to the small number of researchers addressing the issues necessary for the methodological advances of MODIS, emphasis has been given to developing collaborative research and MODIS outreach through the IGBP Data and Information System Framework Activity and through participation in other instrument teams e.g. Eric Vermote in the POLDER, SPOT Vegetation and SeaWifs. Chris Justice represented MODIS at the semi-annual Sellers-Mooney IDS Meetings. Chris Justice also attended the discipline leaders meetings and where possible the weekly MODIS Technical Team (TT) Meetings. Chris Justice chaired and Eric Vermote attended the SDST SAP meetings.

In addition, the goals of the MODIS project, the status of the instrument and preliminary results of the research were presented at a number of key scientific meetings listed below. The project was also represented at the MODIS Science Team meeting. Results of the studies undertaken as parts of the project are in the process of being written up and submitted for publication. Publications are listed below.

b) Tasks Accomplished (Data analysis and interpretation)

Version 1 software

In this reporting period, we have emphasized generation of the V1 code and the associated test data sets. This has consisted of 1) rewriting portions of the code that needed corrections and/or reorganization to improve clarity and simplify processing, 2) identifying and optimizing computationally intensive tasks, and 3) incorporating new and/or replacement modules and functions into the Beta 3 code.

New/replacement routines incorporated into the Beta 3 code:

New BRDF (bidirectional reflectance distribution function)-atmosphere coupling correction module.

Code to utilize ancillary data (DAO and TOMS Ozone) sets.

Revised HDF library to read and write V1 HDF files.

Code to L1B QA flags.

Code to utilize land cover ancillary data base

Code to read Level 3 Land Aerosol product and Level 2 water vapor product.

Revised L2G library package that decreases processing and storage requirements.

Changes/additions to the Beta 3 code:

Modified program to use the V1 cloud mask, which is stored in an entirely different format than the Beta 3 cloud mask product.

Changed code to be in compliance with the requirements specified in the MODIS Software Development Standards and Guidelines document.

Added several new utility functions to eliminate redundant code sequences and make our interface to the SDP Toolkit cleaner and less awkward.

The new ancillary data bases (of which there were many) have been documented and the V1 delivery package produced.

Resolved incompatibilities between our HDF ingest code to work the V1 synthetic data sets, the format of which was undergoing regular changes during some of this period.

Rewrote several program modules to incorporate improvements suggested by the the SDST. Most of these improvements will increase the portability of our code.

Reintegrated original Boston BRDF-atmosphere coupling correction code, which had been removed when we integrated the Montana LUT scheme.

Delivered revised version of code to MODIS SDST 14 June. This version contained several bug fixes and new code to extract granule-specific metadata that had formerly not been available (e.g. the geographic edges of the granule). Most of the bugs were memory-related and caught by the Sentinel memory checking program now being used by the SDST. Several bugs were found in the SDP Toolkit and bypassed.

MODIS / GCM Modeling IDS Interface

A meeting was held with I. Fung of the Sellers / Mooney IDS activity in January at GISS to examine the feasibility of using an aerosol by-product from the AVHRR atmospheric correction /MODIS prototyping activity as an input to the IDS transport models and GCM modeling activities.

Atmospheric PSF aerosol/retrieval correction prototyping

Dr Vermote contributed to work on the LTER/TM atmospheric correction software as a prototype for MOD# 09 validation. Documentation of the code continued. The test data set for the LTER atmospheric correction consists of 15 scenes acquired by the NASA Landsat Global Change Data Collection over the following LTER sites (Sevilleta, Hog Island, National Temperature Lake, Bonanza Creek, HJAndrews). Corrected/Uncorrected scenes were transmitted electronically to LTER-net for evaluation. Atmospheric correction software has been ported to the LTER-net facility. Validation using clear/hazy pair of images has been performed, and optical depth retrievals from TM data from the Dark Target technique using the 2.13mm channel have been compared to coincident AERONET observation (Brent Holben, sunphotometer network) observations. A presentation of the results was made at the Atmosphere Lunch Seminar (Yoram Kaufman) on March 7,1996. Progress is on-going collaborating with Hassan Ouaidrari on refining the aerosol inversion technique and validation of correction. Atmospheric point spread function correction (planned for MODIS) is part of the correction scheme for TM and will be evaluated using those TM data.

Atmosphere/BRDF Coupling

The atmospheric correction algorithm depends in part on the convolution of the diffuse irradiance field with the surface bidirectional reflectance function (BRDF). The former depends on the latter, and the latter cannot be remotely sensed without knowledge of the former. Therefore, the necessary coupling parameters must be evaluated via indirect methods.

J. Privette developed two methods for determining coupling parameters for the code. The first, contained in the Beta delivery (August, 1995), relies on the BRDF linear models produced at Boston University for the BRDF/albedo product. As a result of discussions at the November, 1995 Science Team meeting, we also developed a look up table (LUT) approach similar to that used for the LAI/fAPAR routine (Univ. of Montana). Briefly, we outline the respective approaches and their limitations below.

The first approach allows us to precompute individual terms of the linearized coupling parameters as a function of sun-view geometry and atmospheric optical depth. After retrieving the previous 16-day period BRDF coefficients from the BRDF/albedo product, we linearly combine products of the coefficients and coupling terms to estimate the coupling parameters. This method is simple and depends strongly on MODIS data to estimate the BRDF shape. However, the BRDF models are linear approximations to a non-linear solution, and thus may exhibit significant errors. Moreover, since multiple MODIS samples are needed at each 1 km grid cell to determine the BRDF models, clouds may prevent accurate retrieval of the BRDF coefficients in a given 16-day period. Finally, the BRDF shapes must be considered average over 1 km, although the true shapes may vary at higher spatial resolution.

In the second approach, we used an accurate numerical BRDF model to precompute the coupling parameters for the 11 LAI levels in each of the 6 biomes used by Montana LAI/fAPAR algorithm. This was done for each of the 4 visible-NIR bands, all sun-view geometries and atmospheric optical depths. All values are stored in LUTs.

In operation, we will compare the surface reflectance estimatesÑdetermined without coupling termsÑto the precomputed BRDF values and determine the LAI value which produces the best fit over the first 4 bands. With this result and the aerosol optical depth, we can immediately retrieve coupling parameters from the LUT and recompute the surface reflectance, this time with surface-atmosphere coupling. This method requires angular discretization of the sun-view geometry in the LUT, discretization of the LAI, and accurate prior knowledge of the biome type. Furthermore, many BRDF model parameter values (e.g., leaf and soil reflectance) must be assumed for each biome type such that only the LAI remains variable. However, the coupling parameters can be determined at the resolution of the current MODIS pixel (e.g., 250 m), and can always be evaluated for any sample.

Both coupling parameter methods were operable in our Version 1 delivery (June, 1996), and we continue to evaluate their performance under different scenarios. We have completed a table of grassland and deciduous forest BRDF and coupling terms for the LUT approach. The impact of errors in biome type, fixed parameter values, and discretization of the LUT are being assessed. To date, we have used FIFE AVHRR data in this step, however BOREAS and other data sets will also be employed soon.

CIMEL Surface BRDF Measurements

As part of our efforts, we are evaluating the potential of using a relatively inexpensive CIMEL sun photometer to measure bidirectional reflectance in the field. Subsequent data sets can potentially be used for two purposes: 1) validation of coupling parameters generated by either of the two methods outlined above, and 2) evaluation of the standard MODIS surface reflectance, BRDF and albedo products by CIMEL sensors located on field towers after MODIS launch.

We presently own two CIMEL sensors that are being calibrated via the AERONET program. We have sampled surface reflectance locally and qualitatively verified that appropriate trends were retrieved. We have also developed an automated sampling protocol to collected data at 5¡ angular resolution over the full lower hemisphere. This protocol is presently being coded onto an EPROM chip by CIMEL company personnel. Upon receiving the EPROM, we will colocate the CIMEL next to the PARABOLA instrument (Don Deering, Code 923) and a Barnes MMR radiometer (Betty Walter-Shea, Univ. of Nebraska) to verify that the CIMEL collects data similar to these established BRDF sampling instruments. This validation will be conducted over various canopies (grassland, cropland, forest).

Vegetation Index Compositing (w. Huete)

In collaboration with Alfredo Huete (Univ. of Arizona), we are evaluating simple BRDF models for use in vegetation index compositing (Privette et al., 1996b). Specifically, we compared 10 models by inverting them with subsets of PARABOLA data collected over various canopies. Two models were superior for the estimation of nadir reflectance and spectral albedo. We plan to continue these activities by inverting the models with data from other sensors (ground, aircraft and satellite) to verify initial results. This will conclude with a recommendation of the most accurate BRDF model for VI compositing purposes.

We are also evaluating the most useful sun-view geometry for VI determination. Previously, the nadir sample was desired as this minimized atmospheric effects. Preliminary results (Walter-Shea et al., 1996) suggest that samples at off-nadir angles may be more sensitive to LAI and fAPAR and less sensitive to perturbing factors (leaf angle distribution, solar angle) than are nadir samples. We will continue this activity for different canopy types and data sets. Results of both research topics will be incorporated in the algorithm at V2, to generate monthly composited VI suitable for modeling purposes.

Discussions were initiated with S. Ustin (Univ.Ca Davis/ Sellers-Mooney IDS) to examine the possibility of an advanced IDS product from MODIS on vegetation condition using the middle infrared capability of the instrument.

MODIS Fire Detection (w. Kaufman)

Dr. L. Flynn, Justice, and Kaufman met in March at GSFC to discuss V1 plans for the Fire Code Delivery due in June 1996. The research agenda for Flynn was developed for 1996. Emphasis will be given to refining the emitted energy at-launch product and further developing the smoldering ratio post-launch product. A simulation activity is being conducted by Louis Giglio (GSFC) to test the off-nadir effects on fire detection. Comparisons are on-going with the AVHRR, GOES, and DMSP as part of a fire detection validation activity.

The tasks identified for 1996 that have already been accomplished include: provision of information on fire temperatures to Dr. Kai Yang for incorporation into a MODIS daytime test granule. The Fire granule can be accessed via ftp to modispc.gsfc.nasa.gov, and is located in the directory STIGdata/SyntheticData/Hot. It will provide a means to test the MODIS V1 Fire algorithm using HDF data (exactly the format output by the MODIS SCF). Direction was given on the use of MODIS 3.95 µm channels (21 and 22). Both MODIS 3.95 µm channels will be used in algorithm estimates of fire energy. Strong fires that saturate channel 22, will have energy calculated using the high-gain equivalent channel 21.

Results of the first six months of effort have led to the preparation of two draft papers to be submitted for publication. The first publication arose out of data collected during a trip to San Diego (12/95) to get supplementary spectral data on dry climate vegetation. A flight over the San Diego area provided a unique data set which helped to demonstrate the robustness of an empirical relationship between the reflectance of vegetation at 0.49, 0.66 and 2.2 µm. This relationship will help to separate the reflectance contribution of fire aerosols from that of the natural background. The paper entitled "The MODIS 2.2 µm Channel - Application for Remote Sensing of Aerosol Over the Continents and for Atmospheric Correction" was submitted for publication in early May. Final sections of a second all-encompassing paper detailing the MODIS Fire Products and their method of derivation are currently being written. A section of that paper includes a discussion of fire energy calculations using the University of Hawaii Yellowstone TM data set. Since TM data are 30 m spatial resolution, the data were spatially degraded to MODIS resolution and a comparison of the fire energy from 30 m and 1 km data was accomplished. The results showed that the emitted energy derived from both data sets for identical areas varied by at most only 20%, which means that MODIS estimates of fire energy will be very accurate.

The next step, currently in progress, is to test the empirical energy calculations within the MODIS Fire Algorithm. This will be done with four different types of data. The MODIS Fire granule mentioned above will be used to test the functionality of the code. The 1 km Yellowstone TM data, a hypothetical TM-based data set (saturated pixels in the 1 km Yellowstone data set will be replaced with "realistic" values), and spatially degraded SCAR-B data will also be used for algorithm testing. Yoram Kaufman has derived an empirical relationship to calculate total emitted fire energy from the 3.95

µm MODIS data. Jackie Kendall and Louis Giglio incorporated this relationship into a working version of the MODIS code. Preliminary results using the Yellowstone 1 km data set have shown that the algorithm successfully locates fire pixels. Out of the 210 x 180 pixel Yellowstone image, 3145 pixels were identified as fire pixels. Emitted energy characteristics of those pixels were found to be in agreement with a range of possible smoldering and flaming fire values. Other empirical formulas were tested that had limited success with either strong or weak fires, but not the entire range of fire intensities.

Giglio prepared the first draft of the MODIS Version 1 Fire Product Specification with the assistance of Robert Wolfe. This document contains a detailed description of the file formats of the fire products that will be produced by the MODIS land product code. Giglio is currently working on the V1 L2 fire delivery and Justice is developing the V1 L3 algorithm for delivery in the next reporting period.

In summary, by June 1996, significant advances have been made towards the MODIS Fire at-launch products. We have tested the algorithm and found that it accurately identifies fire pixels. Tests of the empirical emitted energy equation have yielded excellent results. Our remaining tasks are to complete the fire pixel identification and energy calculation tests by looking at the effects that MODIS's triangular response has on these data. Also, using the HDF formatted granule created by Kai Yang, we can test the functionality of the actual MODIS Fire Code. Once these tests have been satisfactorily completed and the at-launch MODIS Fire Algorithm has been thoroughly tested, work will begin on the smoldering/flaming ratio post-launch product.

Giglio has also developed a simulation model to examine the performance of the AVHRR fire detection algorithm which is being used as a prototype for MODIS fire monitoring. A collaboration is being sought with the AVHRR Pathfinder 2 Project and the IGBP Fire Algorithm Working Group to develop an AVHRR 1km Fire Product which will help in MODIS prototyping and developing a fire climatology.

EOS Validation

Chris Justice co-chaired the EOS Test Site Meeting with Diane Wickland (HQ) and worked with Starr, Suttles and Wickland to generate the EOS Test Site Document. The Test Site meeting resulted in the conceptual framework for the EOS Test Site Validation activities. The report is available on the WWW at http: //spso. gsfc.nasa.gov/ validation/docs.html. Jeff Privette compiled and merged the various validation contributions from the land group into the MODLAND validation document and overheads currently being carried by the EOS Validation Office. These documents are currently being reduced to a revised set of summary vu-graphs.

The EDC DAAC Science Advisory Panel

Chris Justice attended this meeting and represented MODIS concerns to the Land DAAC. He listed the new members on the MODIS Team and briefly explained their roles. He also provided updates or commented on the MODIS validation plan, QA system design,
common processing requirements, inter-instrument data dependencies, MODIS processing design, and various DAAC-related issues. Attention was given to recent increases in MODIS data processing and archiving loads. Justice requested more emphasis from the DAAC on MODIS related issues such as ground control points, land sea mask and production planning.

Meetings Attended

Aerosol IDS Meeting in New York: January 4-5th

SAGE III Algorithm review: January 17-18th

MCST Science Advisory Panel: January 23th

MODIS Fire Algorithm Meeting: March 5-6

MVI Meeting: March 12-13th

EOS Test Site Meeting: March 14-15th

POLDER Science Team Meeting: March 20-25th

Aerosol Workshop (DC, ASAE) : April 15-19th

SeaWiFS/SeaDAS Tutorials - April 23-24th

MODIS Team Meeting:May 1-3rd

SWAMP Land Review: May 15-16th

EDC DAAC SAP: May 6-8th

European Geophysical Society, The Hague: May 6-10th

EOS IDS Meeting, Victoria : May 8-10th

EOS Calibration/Validation Meeting (GSFC) : May 8-10th

NOAA/MODIS Operational Satellite Meeting (Suitland): June 5th

NOAA NPOES Meeting: June 10-11th

Global 1km AVHRR Ground Station Operators Meeting (Annapolis)- June 14th

BOREAS Experiment Meeting, Toronto, Can.: May 20-24th.

IGARRSÕ96 Conference, Lincoln, NE: May 29-31th

Publications

Braswell, B. H., D. S. Schimel, J. L. Privette, B. Moore III, W. J. Emery, E. Sulzman and A. T. Hudak (1996), Extracting ecological and biophysical information from AVHRR optical measurements: a new algorithm based on inverse modeling, *J. Geophys. Res.*, in print.

Kaufman, Y.J., A. Wald, L.A. Remer, B. Gao, R. Li, and L. Flynn, The MODIS 2.2 µm Channel - Application for Remote Sensing of Aerosol Over the Continents and for Atmospheric Correction, Submitted May 1996.

Kaufman, Y.J., C.O. Justice, L.P. Flynn, E. Prins, D.E. Ward, A. Setzer, Monitoring Global Fires from EOS-MODIS, in preparation.

Privette, J. L., R. B. Myneni, W. J. Emery, and F. G. Hall, Optimal sampling conditions for estimating grassland parameters via reflectance model inversions (1996), *IEEE Trans. Geosci. Remote Sens.*, 34(1):272-284.

Privette, J. L., D. W. Deering and T. F. Eck (1996), Estimating albedo and nadir reflectance through inversion of simple BRDF models with AVHRR/MODIS-like data, *J. Geophys. Res.*, submitted.

Privette, J. L., W. J. Emery and D. S. Schimel (1996), Inversions of a vegetation reflectance model with NOAA-AVHRR data, *Remote Sensing Environ.*, in print.

Roger, J. C. and Vermote, E. F. (1996), Computation and use of the reflectivity at 3.75mm from AVHRR channels, submitted to R.S.E.

Vermote E., and Roger J.C., 1996, "Radiative Transfer Modeling for Calibration and Atmospheric Correction" chapter 3 of Advances in the use of NOAA AVHRR for Land Applications, D'Souza, G., Belward,A.S and Malingreau,J.P (Eds.), 1996, pp 49-72, published by Kluwer Academic Press, Dordrecht,. 479pp.

Vermote E and El Saleous Nazmi, 1996, "Absolute Calibration of AVHRR channel 1 and 2" chapter 4 of Advances in the use of NOAA AVHRR for Land Applications, D'Souza, G., Belward,A.S and Malingreau,J.P (Eds.), 1996, pp 73-92, published by Kluwer Academic Press, Dordrecht,. 479pp.

Vermote, Nazmi El Saleous, and Brent N. Holben, 1996 "Aerosol Retrieval and atmospheric correction" chapter 5 of Advances in the use of NOAA AVHRR for Land Applications, D'Souza, G., Belward,A.S and Malingreau,J.P (Eds.), 1996, pp 93-124, published by Kluwer Academic Press, Dordrecht,. 479pp.

Vermote, E. F., El Saleous, N. Z., Justice, C. O., Kaufman, J. Privette, Y. J., Remer , L., Roger, J. C. and Tanre, D. ,1996, Atmospheric correction of visible to middle infrared EOS-MODIS data over land surface, background, operational algorithm and validation, Journal of Geophysical Research, (accepted).

Vermote, E. F., Tanre D., Deuze, J. L., Herman, M. and Morcrette, J. J. (1996), Second Simulation of the Satellite Signal in the Solar Spectrum: an overview, accepted to IEEE Trans. Geosci. Remote Sens.

Walter-Shea, E. A., J. L. Privette, D. Cornell, M. A. Mesarch, and C. J. Hays (1996), Sensitivity of relations between spectral vegetation indices and absorbed radiation and leaf area index in alfalfa, *Remote Sensing Environ.*, submitted.

Conference Papers

Asner, G., J. L. Privette, C. A. Wessman and C. A. Bateson (1996), Extracting sub-pixel vegetation endmember bidirectional reflectance for canopy model inversion using NOAA AVHRR satellite imagery, *IGARSS'96*, Lincoln, NE, V. III: 1663-1665.

Braswell, B. H., J. L. Privette, and D. S. Schimel (1996), A technique for combining geometrical and spectral BRDF information for retrieval of plant canopy characteristics using AVHRR optical data, *IGARSS'96*, Lincoln, NE, 23 May 1996.

***** This report provides a summary of project activities during the reporting period for further information contact the investigators listed above.